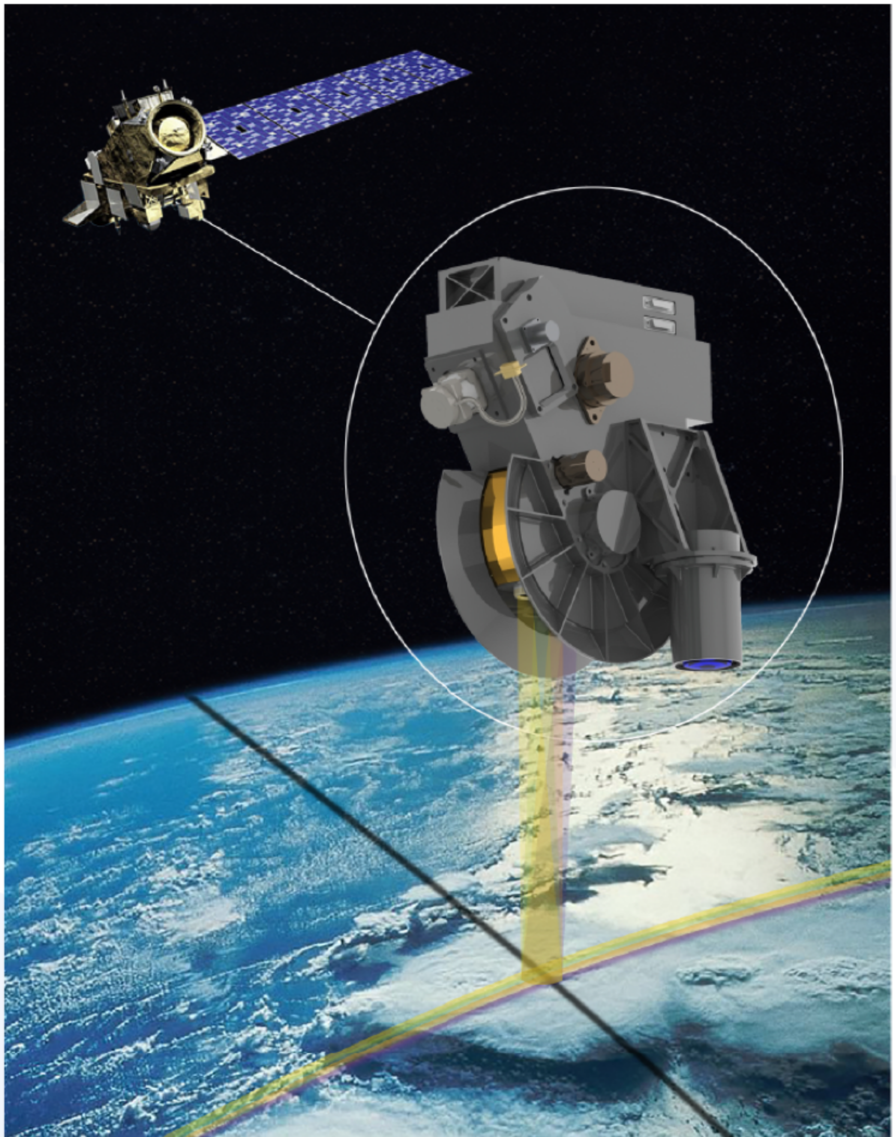
Libera

Understanding Earth's Energy Budget

LASP • JPL • LBL • UA • CSU • UM • NIST • NOAA • Ball • SDL

Libera, EVC-1 Mission

Li'be-ra, named for the daughter of Ceres in ancient Roman mythology



Provides continuity of the Clouds and the Earth's Radiant Energy System (CERES) Earth radiation budget (ERB).

- Measures integrated shortwave (0.3–5 µm), longwave (5–50 µm), total (0.3–>100 µm) and (new) split-shortwave (0.7–5 µm) radiance over 24 km nadir footprint.
- Includes a wide FOV camera for scene ID and simple ADM generation to pave way for future free-flyer ERB observing system.

Innovative technology:

- Electrical Substitution Radiometers using VACNT detectors

Operational modes:

- Cross-track and azimuthal scanning; on-board calibrators; solar and lunar viewing.

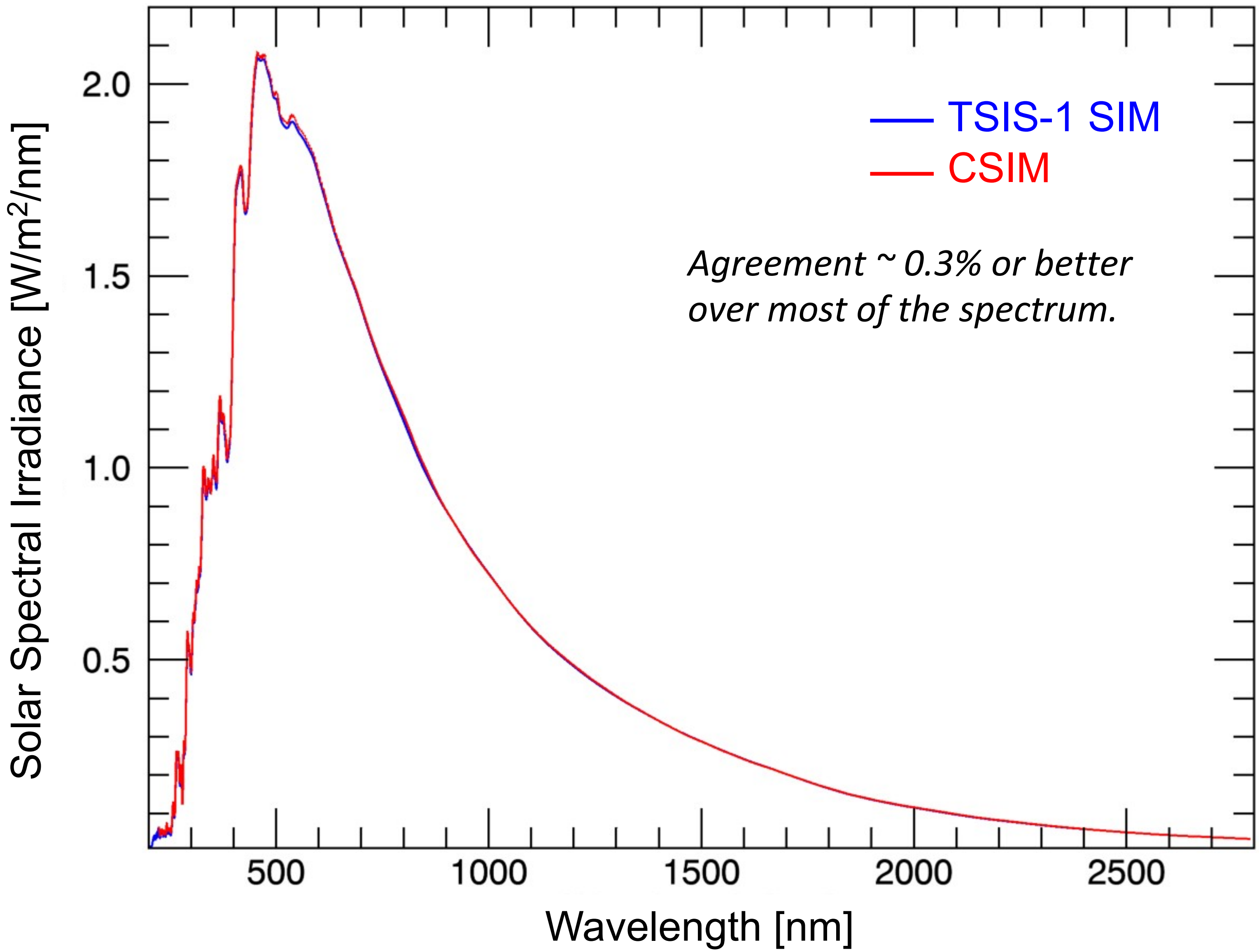
Flight:

- JPSS-3, 2027 launch; 5-year mission

Partners:

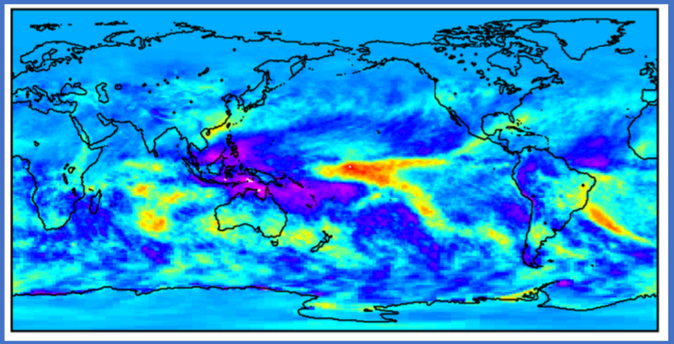
- LASP, Ball Aerospace, NIST Boulder, Space Dynamics Lab; CU, JPL, CSU, UA, UM, LBL

On-Orbit Demonstration of ESRs Using VACNTs



Libera guided by the ERB Science Working Group Report

RECOMMENDED MEASUREMENT AND INSTRUMENT CHARACTERISTICS FOR AN EARTH VENTURE CONTINUITY EARTH RADIATION BUDGET INSTRUMENT



National Aeronautics and Space Administration

- Science Working Group formed February, 2018.
- Working Group consisted entirely of civil servants to avoid Federal Advisory Committee Act rules given time constraints.
  - 22 NASA and NOAA CS personnel.
- Goal of SWG to recommend instrument and measurement characteristics for a continuity-preserving instrument, within cost cap.
- Recommended solution was basically FM6, maybe with reduced scanning capability. (Cross track, with azimuthal rotation capability for lunar/solar calibration.)
- **Note: recommendations are not AO requirements!**
- SWG met periodically from February to August.
- First draft July 2018 published for public comment.
- Comments informed final draft.
- Final draft is complete.
- Final draft will be made available on NASA web site, and referenced in AO.

Presentation by David Considine, NASA HQ, at 2018 Earth Radiation Budget Workshop

Recommended Observational Characteristics

- Should include onboard calibration.
- Should conduct periodic solar and lunar calibration.
- Instrument characterization and ground calibration traceable to NIST standards.
- Class C with a 5-year nominal lifetime.
- Should be within 15 min of a 13:30 local equator crossing time.[2]
- Minimum of 6 months overlap with at least one of the remaining CERES instruments.
- Should fly on the same satellite or within 3 min. of an imager with spatial resolution and spectral channels similar to VIIRS.

[2] All CERES instruments except those on Terra are in an ascending sun-synchronous orbit with a 13:30 local equator crossing time.

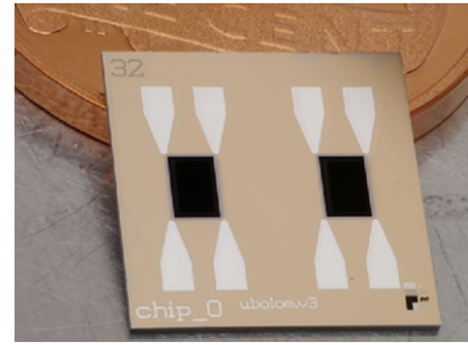
Recommended Measurement Characteristics

- Measurements: Earth-emitted longwave radiance (0.5% uncertainty) and Earth-reflected solar radiance (1.0%) over the three unique broad bands, 20-25 km nadir spatial resolution, daily full-global coverage:
  - Shortwave reflected solar radiation, 0.3 to 5 µm (0.17% uncertainty)
  - Emitted longwave radiation, 5 to 50 µm (0.24% uncertainty)
  - Total outgoing radiation: 0.3 to >100 µm (0.22% uncertainty)

- CERES FM6 on NOAA 20 has the above three channels. These are the preferred channels in the science working group report.
- CERES FM1-FM5 does not have 5-50 µm channel but does have a window channel from 8-12 µm.
- Each instrument has independent and identical co-aligned and co-registered telescopes.
- *Libera* adds a split shortwave channel, 0.7–5 µm. (0.17% uncertainty)

Libera Calibration and Characterization

- Component-Level Characterizations
  - Properties of all optical surfaces (mirrors, filters, detectors) measured at NIST and PTB, Germany
  - Used in instrument model to generate expected spectral response functions
- Radiometer Calibrations
  - End-to-end channel calibration at LASP against NIST-traceable absolute irradiance standard detector
  - Uses laser tie-points from 300 nm to 184 µm and broadband blackbody sources.
- System Level Validation
  - Integrated system transported to SDL for independent validation using SW & LW targets at a facility developed for RBI

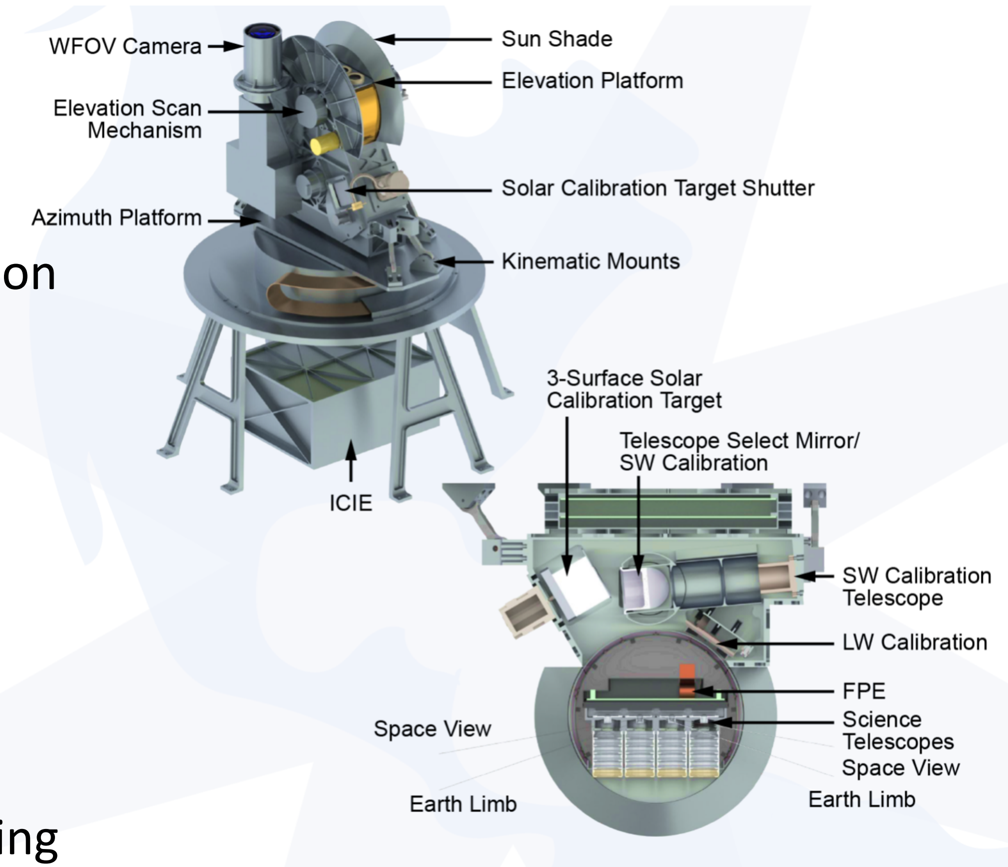


Libera utilizes advanced carbon nanotube detector technology developed by LASP and NIST over a number of IIP projects (BABAR ACT, CTIM-FD, CAESR, and CSIM-FD). Libera prototype detector shown along with a penny

On-Orbit Calibration and Validation

A *belt-and-suspender* approach:

- Onboard calibration targets
  - Shortwave calibrator using LED sources and engineered diffuser; stability tracked via a SW calibration radiometer
  - Longwave calibrator: flat-plate blackbody (300-350K) with CNT coating, Si-traceable PRTs to NIST standards.
- Solar calibrations
  - Three Spectralon diffusive panels duty-cycled for degradation tracking
- Lunar calibrations
  - Obtained during JPSS SC roll maneuvers for VIIRS lunar calibration



Transfer of Mission Operations to the RBSP

- *Libera* has a planned 1-year Phase E mission operations.
  - During this time Libera produces L-1b radiance products for the RBSP to ingest and produce higher level ERB data products.
- After one year operations are transferred to the RBSP for the production of L-1b data.
- *Libera* science team activities continue for a full 5-years
  - Primary science data processing of split channel radiance
  - Production of camera radiances and derived products
  - Addressing *Libera* science objectives

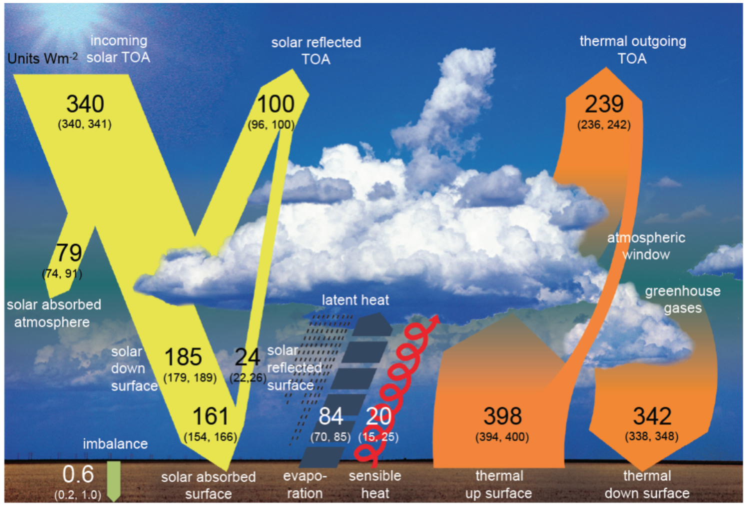
Libera Science Goals

Overarching goals:

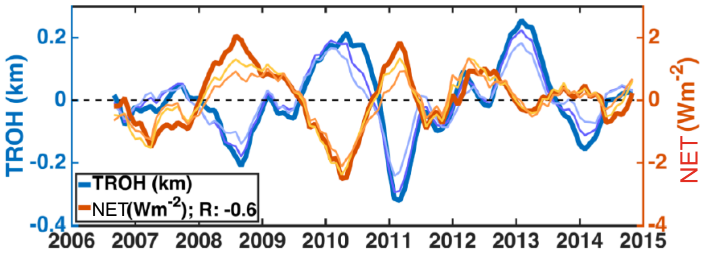
1) **Provide seamless continuity of the ERB measurement with characteristics identical to CERES**
    - Prevents gap in ERB data record (CDR) critical for studies of global climate change
    - Tied to **Science objective 1**: Use extended CDR to identify and quantify processes responsible for the instantaneous to decadal variability of ERB

2) **Develop a self-contained, innovative, affordable observing system:**
    - Novel, miniaturized detectors greatly improve accuracy & stability and pave way toward smaller & cost-effective follow-on projects.
    - To separate from VIIRS-like imager, *Libera* tests a miniature wide field-of-view camera to provide scene & angular context crucial for radiative flux retrieval
    - Tied to **Science objective 2**: Develop angular models and algorithms for scene identification using camera radiances

3) **Provide new and enhanced capabilities that support extending ERB science goals**
    - Employ Split-Shortwave channel to derive SW VIS and NIR fluxes and quantify SW energy disposition
    - Tied to **Science objective 3**: Revolutionize understanding of spatio-temporal variations in SW, VIS & NIR fluxes



Top: Earth's radiation budget. TOA and surface fluxes presently derived from CERES and ancillary observations are invaluable for understanding ERB variability, constraining climate sensitivity & feedbacks, and studying climate processes. As an example (below) we present the co-variability of TOA net radiative flux with tropopause height, an indicator for convective intensity that is sensitive to surface temperature perturbations.

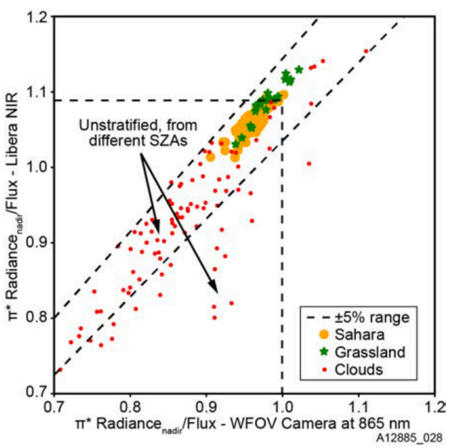


Libera Science Objectives

Science Objective 2:

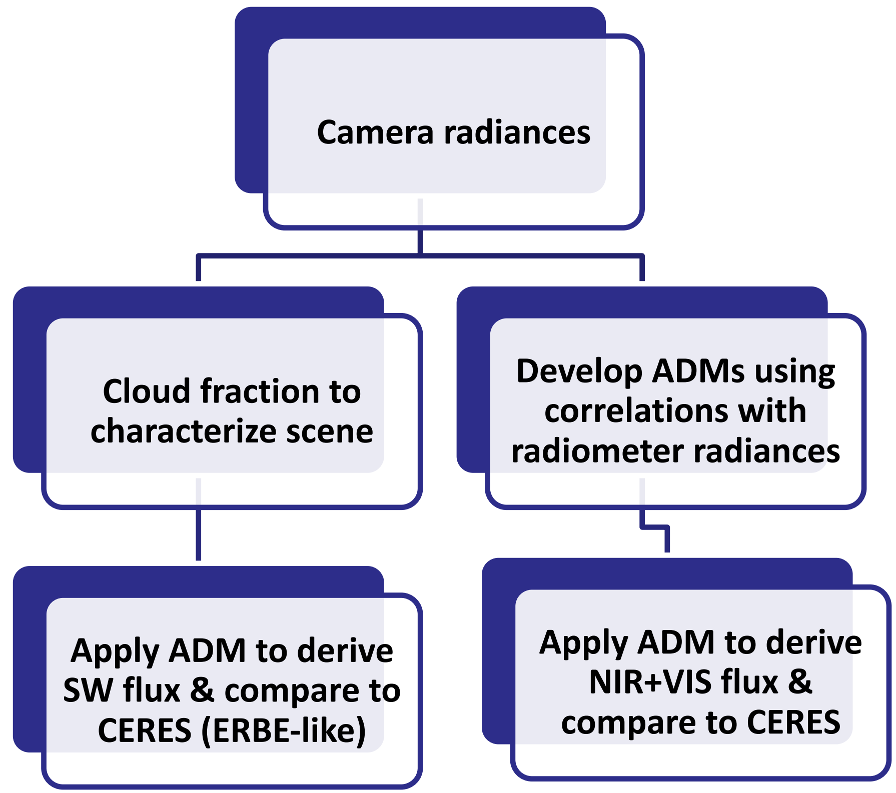
Develop angular models (ADM) & scene identification algorithm using WFOV camera radiances

- Camera experiment provides additional angular information for development of NIR ADMs (ERBE-like) through correlations with radiometer radiances



Anisotropy factors for nadir-radiance-to-flux conversion of NIR band versus narrow-band (865nm) camera observations, derived from OSSEs for Europe & Northern Africa under clear-sky (yellow & green) and cloudy conditions (red). Results show that camera radiances can serve as proxy for NIR radiance. The established camera-NIR relationship will be pegged to collocated NIR cross-track observations and stratified by scene type.

- Provides the means to derive **cloud fraction** needed to apply ERBE-like ADMs in radiance-to-flux conversion (NIR, VIS)
- Experimental products of cloud fraction and NIR & VIS fluxes (L2x)

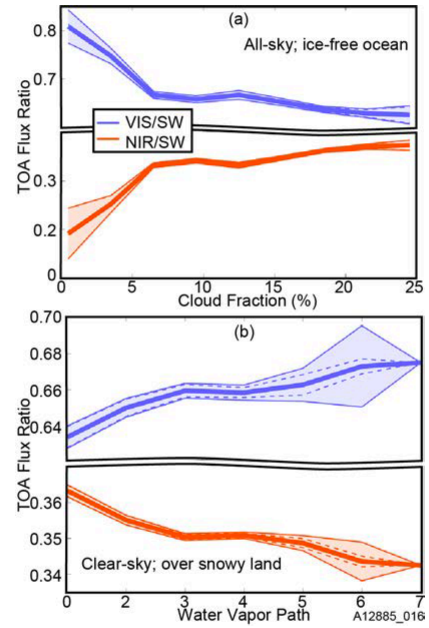


Libera Science Objectives

Science Objective 3:

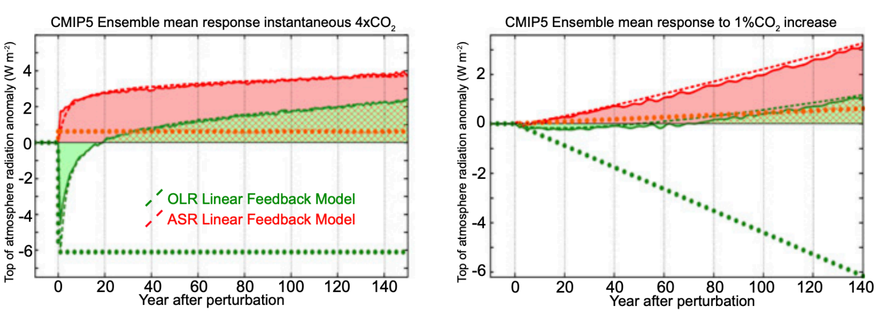
Revolutionize our understanding of spatio-temporal variations in SW, VIS & NIR fluxes

- **NIR & VIS fluxes at TOA & surface, all- & clear-sky**
- **Characterize NIR & VIS signatures of processes that control absorption of solar radiation, SW climate feedbacks, and the hemispheric symmetry of planetary albedo.**



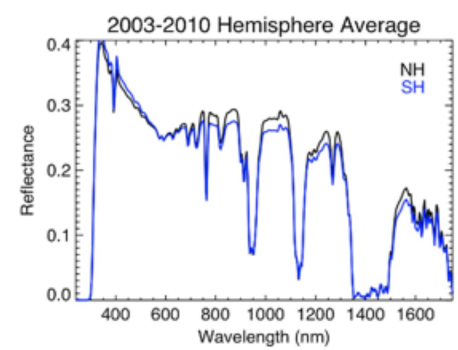
1) a) The effect of changing cloud fraction over oceans preferentially enhances NIR reflected flux compared to VIS, while total SW (VIS+NIR) flux increases.

b) The effect of changing water vapor path above snow covered land conversely decreases NIR and increases VIS reflected flux, while total SW flux decreases.



2) CMIP5 Ensemble mean response to instantaneous $4xCO_2$ (left) and to $1\%CO_2$ increase (right): SW absorption sustains global warming on centennial time scale; positive SW climate feedbacks are set into motion by OLR decrease (Donohoe et al., 2014)

3) Planetary albedo is symmetric across hemispheres, but NIR & VIS contributions differ. What are the processes controlling this stabilization? Hypothesis: SH clouds vs. NH land.



Libera Science Team

	Peter Pilewskie, PI	CU LASP	
Maria Hakuba, DPS	JPL	Sebastian Schmidt, Co-I	CU LASP
Graeme Stephens, PS	JPL	Tom Vonderhaar, Co-I	CSU
Odele Coddington, Co-I	CU LASP	Zhien Wang, Co-I	CU LASP
Bill Collins, Co-I	LBL	Chris Yung, Co-I	NIST
Xiquan Dong, Co-I	U. AZ	Sandie Collins, Liaison	Ball
Daniel Feldman, Co-I	LBL	Thomas Kampe, Liaison	Ball
Jake Gristey, Co-I	CU	Jim Leitch, Liaison	Ball
Dave Harber, Inst. Sci.	CU LASP	Richard Allan, Collab.	UR/UK
Xianglei Huang, Co-I	U. MI	Alejandro Bodas-Salcedo, Collab.	UKMET
Bruce Kindel, Co-I	CU LASP	Doris Folini, Collab.	ETHZ
John Lehman, Co-I	NIST	Jacqueline Russell, Collab.	IC/UK
Steve Massie, Co-I	LASP	Martin Wild, Collab.	ETHZ

Summary

Libera will:

- Measure broadband scattered SW and emitted LW radiances at climate quality levels of accuracy, precision, and stability.
- Maintain continuity and extend the ERB climate record
- Produce the daily global set of Level 1b radiances for the RBSP
- Demonstrate a pathway toward a sustainable, reproducible, and innovative observational approach that:
  - Enhances scientific merit
  - Reduces cost and the risk of gaps in future ERB measurements
  - Enables technology infusion to enhance capabilities of a future climate